High purity LPE GaAs for far infrared blocked impurity band detectors

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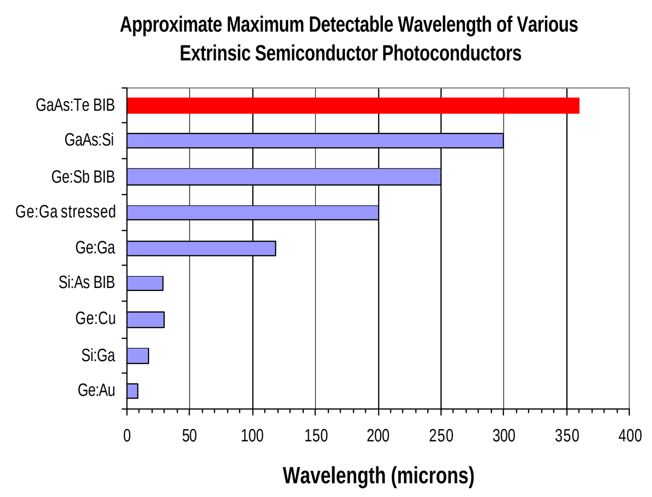
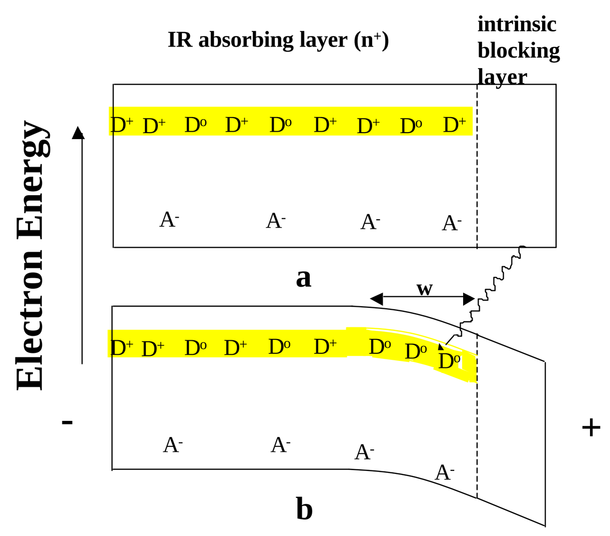
Photoconductive Devices - Current technology and future trends



- High efficiency, low noise photoconductors that can detect light beyond 200μm are currently not available.
- GaAs detectors can extend the long wavelength cutoff beyond stressed Ge:Ga because of the small shallow donor ionization energy (~6meV)

BIB Detector Design and Operation



Energy band diagram of a BIB detector: **a**) unbiased **b**) with an applied bias

- Photon absorption in n+ region.
- Photo-ionized free carriers transport in the conduction band, through the blocking layer into the contact.
- D^+ move toward the negative contact.
- Electrons in the donor band cannot pass through the blocking layer since no such band exists there.

Requirements for Efficient BIB Operation

- The blocking layer should be as pure as possible(N_d-N_a≤10^{11} to 10^{12}cm^{-3}) to minimize the possibility of electron trapping at an ionized donor or deep level and to maintain a high and uniform electric field across the region.
- The absorbing layer should be highly doped (N_d≈10^{15}cm^{-3}) but have very low compensating (minority) impurity concentration in order to maximize the depletion region thickness.

depletion region thickness $$w=\sqrt{\frac{2ee_0(V_a-V_{bi})}{eN_{minority}}+b^2}-b$$

b=blocking layer thickness

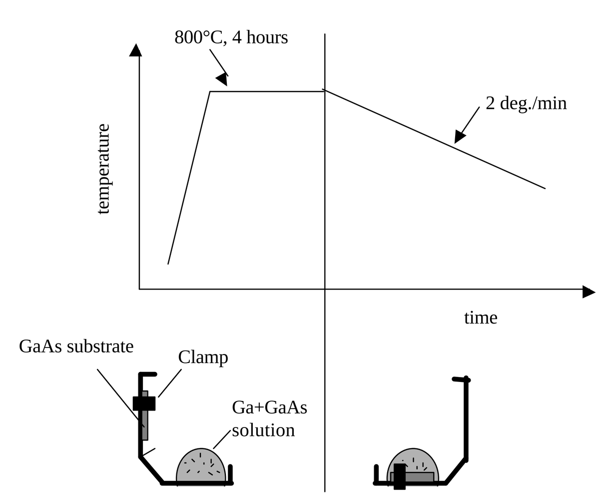
Predicted single pass BIB absorption versus minority doping concentration

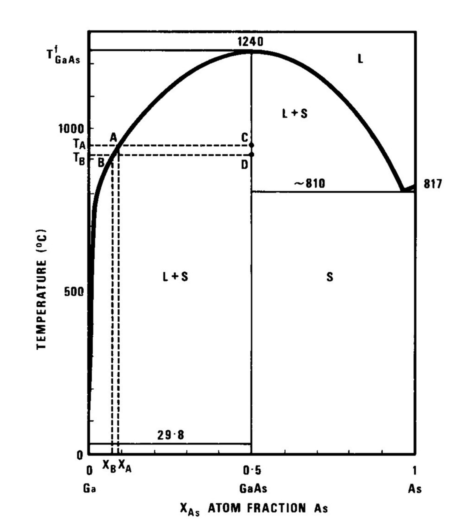
N_d=1x10^{15} cm^{-3}, α=125* cm^{-1}, b=5 μm

N_a (cm^{-3})	Bias (V)	w (μm)	Percent Absorption
1x10^{13}	1.5	10	12
5x10^{12}	1.5	16	18
1x10^{12}	1.5	41	40
7x10^{11}	1.5	50	46
5x10^{11}	1.5	60	53

* Bosomworth, Crandall, Enstrom, 1968

Liquid Phase Epitaxy of GaAs – growth of the blocking layer





- The purity of LPE GaAs films is a result of the segregation of impurities into the liquid phase during growth, as in bulk semiconductor growth, and the availability of very high purity Ga solvent material (99.99999%).

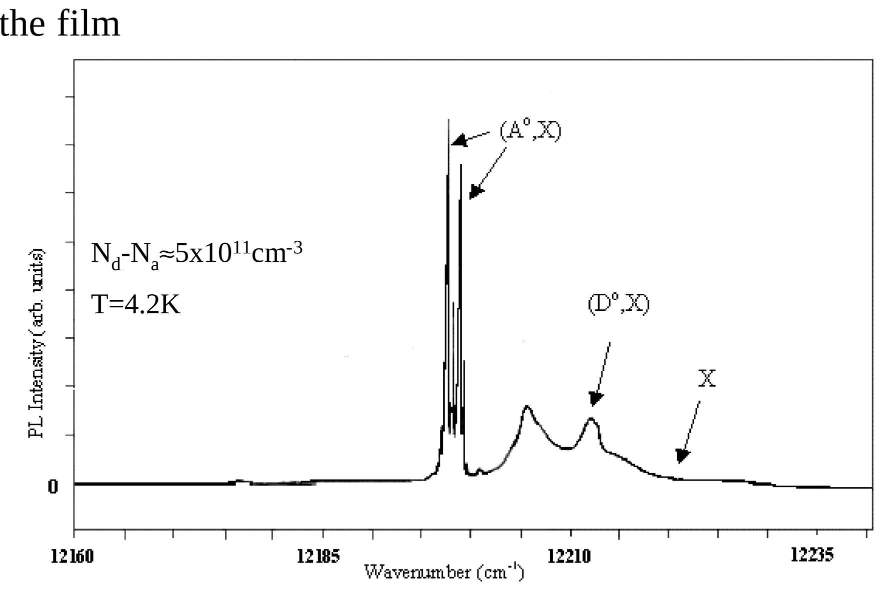
Blocking layer characterization

- **Hall effect and resistivity** measurements determine the net impurity concentration and carrier mobility.
  - $|N_d$-$N_a|$=2x10^{12} cm^{-3} μ_{77}=180,000 cm^2/V-s
- **Capacitance-Voltage** measurements determine the net space charge

  $|N_d$-$N_a|$=5x10^{11} cm^{-3}
- **Photoluminescence** can be used to identify individual acceptor species.
  - Major acceptor: C
- **Magneto-photoluminescence** (courtesy of M. Thewalt, Simon Fraser University) can be used to identify individual donor species.
  - Major donors: S, Si

Photoluminscence of shallow dopants in an ultra-high purity GaAs film

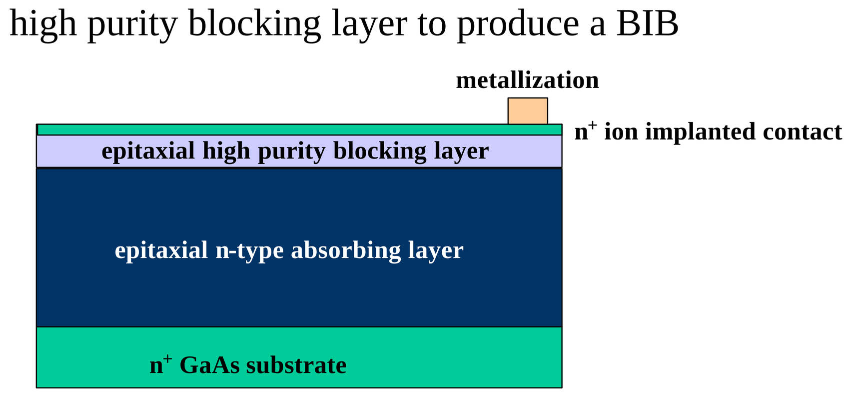
Extremely sharp luminescence lines and presence of the free exciton peak confirm the very high purity of the film



Photoluminescence spectrum of GaAs epilayer 211SI

Future Work - BIB Production

Once the ability to grow highly doped, low compensation absorbing layers has been developed, it will be combined with a high purity blocking layer to produce a BIB



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